Design of Brushless Permanent-Magnet Motors

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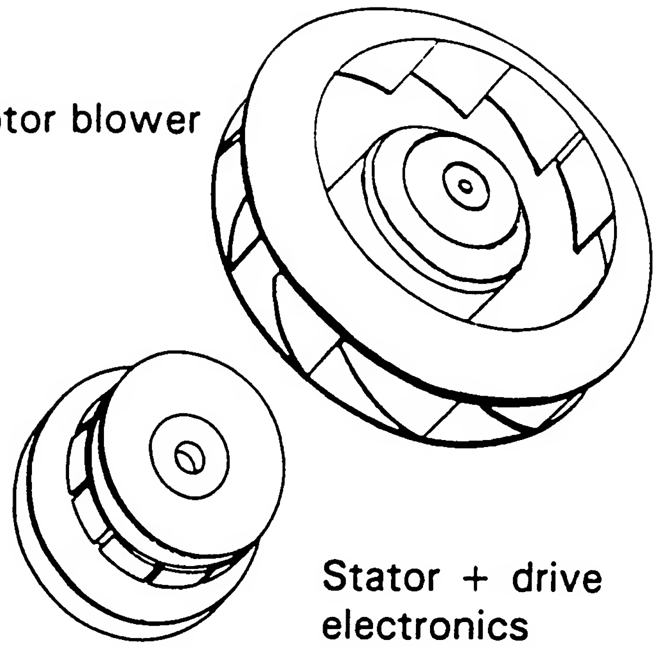

Fig. 2.7 Brushless blower motor

high rotor inertia

In general, exterior-rotor brushless motors are used for continuous-speed applications and the magnet grades are normally the lower-cost versions of bonded rare-earth, bonded or sintered ferrite grades. Their popularity continues because of their low cost and ease of manufacture.

2.4 Pancake or disc-type brushless motors

There are many applications for which the packaging of the pancake brushless motor is extremely convenient. These *axial-gap* motors normally consist of a steel disc rotor with a magnet shaped like a washer cemented to one side of the disc. The materials used are either sintered ferrites or bonded rare-earth. They can be easily magnetized with as many poles as necessary. The stator usually consists of either printed-circuit windings or individual wound coils cemented to a printed circuit board. Fig. 2.8 is a cutaway drawing of a brushless DC pancake motor used to drive the turntable of a record player. Notice the 6 coils of the stator mounted to a round plate. The magnet is cemented to a steel rotor to which the turntable is mounted. To ensure smooth low-speed performance an extra magnet ring is located on the outer periphery of the rotor with many poles magnetized on its rim.

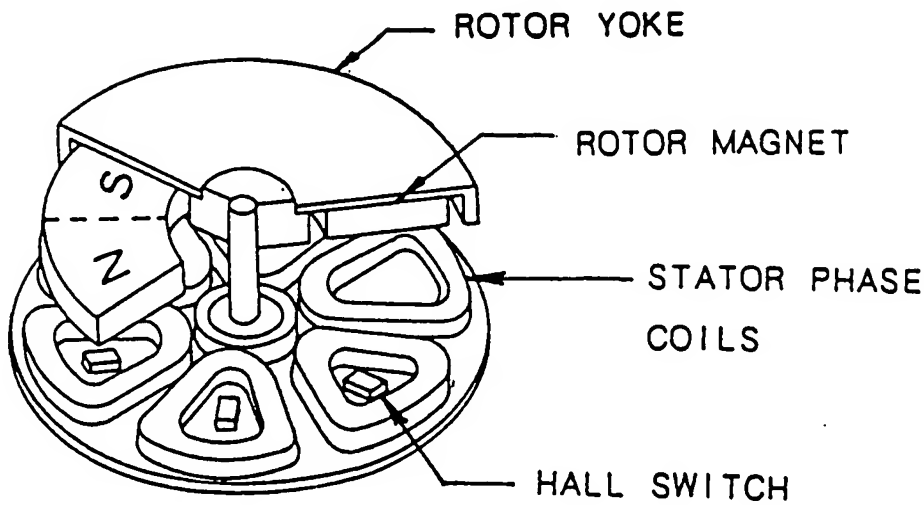

Fig. 2.8 Brushless axial-gap pancake motor for turntable

A pickup coil on the outside of the stator coils generates a tachometer signal for closed-loop velocity control, creating a very smooth low speed performance.

There is a very wide variety of configurations for the axial-gap pancake brushless motor. Fig. 2.9 shows examples.

The main advantages of these motors are their low cost, their flat shape, and smooth rotation with zero cogging. The air gap between the magnet and the stator back-iron is very large, and this results in high leakage of magnetic flux. Although this implies an inefficient magnetic circuit design, it is not a hindrance for the applications utilizing this motor since most of these require low torque. However, if axial-gap motors are used at speeds much above 1000 rev/min, eddy-current losses and heating may be excessive in the steel backing plate of the stator. There are possibilities of providing a laminated structure such as a spiral ribbon of steel or even amorphous iron, wrapped up to form the stator yoke. It is also possible to eliminate eddy-currents by allowing the backing plate to rotate with the magnets while the stator coils remain stationary, held by a non-metallic structure. Such techniques have been adopted for prototypes or R&D demonstrators of axial-gap motors in larger sizes, but they can be so complicated as to make the radial-gap motor far more cost effective in higher-speed, higher-power applications.

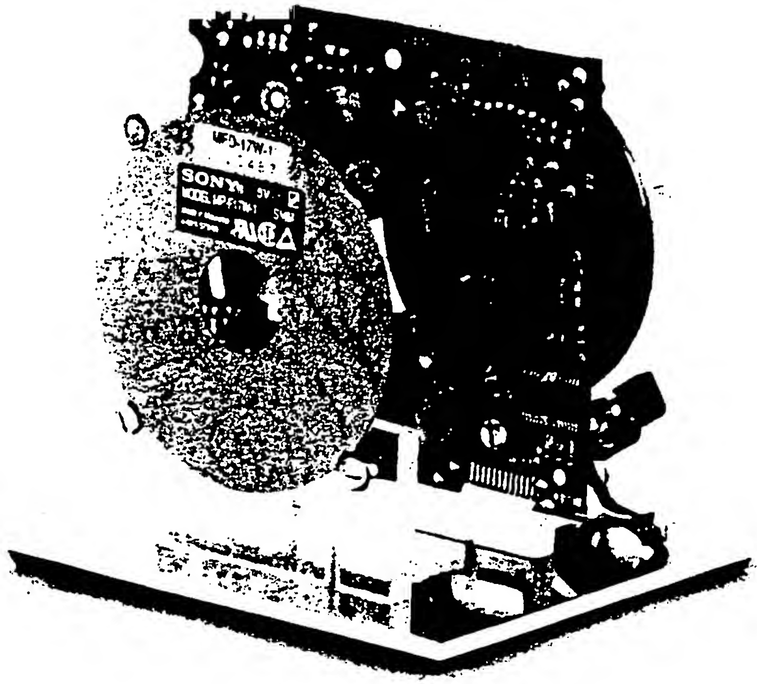

Fig. 2.9 Axial-gap brushless motor components. (By kind permission of Sony)

2.5 Slotless motors

Fig. 2.10 shows the configuration of a slotless motor and Fig. 2.11 shows a finite-element flux plot. The rotor construction is similar to that of the conventional interior-rotor motor. The stator consists of a stack of washer-shaped laminations that make a smooth-bore cylinder with a fairly large airgap that accommodates the windings. The phase coils are pre-wound before assembly and this permits variations in winding techniques that are not feasible with slotted stators. For example, helical windings or Gramme ring windings can be used, with very short end-windings. The space available for windings is virtually doubled by the absence of the stator teeth, and this helps to achieve low copper losses, but the flux-density is reduced because of the large airgap and this machine therefore naturally has a higher electric loading and a lower magnetic loading than conventional motors with slotted stators.

The conductors are exposed to the rotating magnet flux and it may be necessary to use stranded conductors to limit eddy-current losses. Also the winding must be accurately balanced to prevent circulating currents.